Docket No. 1374.43296X00
Serial No. 10/733,377
October 14, 2005

REMARKS

The concurrently filed RCE Transmittal is noted. The present amendments constitute the necessary Submission for this RCE Transmittal. In view of this concurrently filed RCE Transmittal, it is respectfully submitted that the present amendments are to be entered as a matter of right, notwithstanding Finality of the Office Action mailed July 14, 2005.

In this Office Action mailed July 14, 2005, which the Examiner indicated was responsive to the Amendment filed April 27, 2005, the Examiner indicated that claims 1-19 were pending in the application. However, note that new claims 20-26 were added to the above-identified application in the Amendment submitted April 27, 2005. Clarification of the failure by the Examiner to consider claims 20-26 in the Office Action mailed July 14, 2005, is respectfully requested. In any event, it is respectfully submitted that upon any further action by the Examiner in the above-identified application, claims 20-26 clearly are pending claims in the above-identified application and <u>must</u> be considered therein.

In Item 1 on page 2 of the Office Action mailed July 14, 2005, the Examiner indicates that this Action is a "first Office action on the merits" of the above-identified application. Clearly, this statement by the Examiner is incorrect; and the Examiner is respectfully requested to clarify further Office Actions, if this statement in Item 1 is maintained.

Applicants have amended their claims in order to further clarify the definition of various aspects of the present invention. Specifically, Applicants have amended each of claims 1 and 8 to recite that the cobalt film is deposited at a temperature lower than a

temperature at which a reaction layer of silicon and cobalt is formed on the interface between the "bare" silicon substrate "surface" and the cobalt film; and claims 1 and 8 have been further amended, and claim 17 has been amended, to recite that the temperature, lower than the temperature at which the reaction layer is formed, is maintained until the end of the depositing of the cobalt film. Note, for example, pages 15 and 16 of Applicants' Substitute Specification submitted with the Preliminary Amendment filed January 8, 2004, in the above-identified application (hereinafter "Applicants' Substitute Specification"). Moreover, claim 5 has been amended to recite that the first-stage heat treatment is for forming a "disilicide" layer; that the second-stage heat treatment is for "forming" the main component of the "monosilicide" layer; and that the third-stage heat treatment is for forming a main component of the cobalt disilicide layer by converting from cobalt monosilicide to cobalt disilicide.

In addition, Applicants are adding new claim 27-30 to the application. Claims 27-29, dependent respectively on claims 1, 8 and 17, recite that the temperature at which the cobalt film is deposited is a temperature lower than that at which a reaction layer of any cobalt silicide is formed. Claim 30, dependent on claim 1, recites that in the first step the silicon substrate is held by an electrostatic chuck which dissipates heat from the silicon substrate.

As to the newly added claims, note, for example, pages 15 and 16 of Applicants' Substitute Specification.

Applicants respectfully submit that all of the claims presented for consideration by the Examiner patentably distinguish over the teachings of the prior art applied by the Examiner in rejecting claims in the Office Action mailed July 14, 2005, that is, the

teachings of the U. S. patents to Inoue, No. 6,136,699, to Murphy, et al., No. 6,117,771, and to Agnello, et al., No. 6,440,851, under the provisions of 35 USC 102 and 35 USC 103.

It is respectfully submitted that these references as applied by the Examiner would have neither taught nor would have suggested such a fabrication method of a semiconductor integrated circuit device as in the present claims, including, inter alia, the first step of depositing a cobalt film on a bare silicon surface of the main surface of the silicon substrate, and wherein, in this first step of depositing the cobalt film, the film is deposited at a temperature lower than a temperature at which a reaction layer of silicon and cobalt is formed on the interface between the bare silicon substrate surface and the cobalt film, this temperature lower than a temperature at which the reaction layer is formed being maintained until the end of the cobalt film deposition step, and with a further step of heat treating the substrate to form a silicide layer on the interface between the silicon substrate and the cobalt film. See claim 1. Note also claims 8 and 17.

Furthermore, it is respectfully submitted that these references would have neither taught nor would have suggested such a fabrication method, including, inter alia, the temperature of deposition of the cobalt film, which temperature is maintained until the end of depositing the cobalt film, as discussed previously, and wherein an oxidation barrier film is formed over the main surface of the silicon wafer having the cobalt film deposited thereover (see claim 7; note also claims 8 and 17), with a silicide layer having dicobalt silicide as a main component being formed in a second sputtering chamber in which the oxidation barrier film is deposited, the main component of the silicide layer

being converted from dicobalt silicide to cobalt monosilicide, thereafter the oxidation barrier film and an unreacted portion of the cobalt film are removed from the main surface of the silicon wafer, and thereafter the main component of the silicide layer is converted from the cobalt monosilicide to cobalt disilicide by a third-stage heat treatment at a temperature higher than the temperature of the second-stage heat treatment. See claim 8; note also claim 17. See also claim 5, with respect to the heat treatments.

Additionally, it is respectfully submitted that these applied references would have neither disclosed nor would have suggested such fabrication method as in the present claims, including the temperature at which the cobalt film is deposited and wherein an oxidation barrier film is deposited over the cobalt film, with a silicide layer having, as a main component, dicobalt silicide being formed over the surface of semiconductor regions constituting source and drain regions of a MISFET formed over the substrate, and wherein the main component of the silicide layer is converted from dicobalt silicide to cobalt monosilicide by heat treatment, thereafter the oxidation barrier film and an unreacted portion of the cobalt film is removed, and thereafter the main component of the silicide layer is converted from cobalt monosilicide to cobalt disilicide by heat treating the silicon substrate at a third temperature higher than the second temperature. See claim 17.

Furthermore, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested the other features of the present invention, as in the remaining claims, having features as discussed previously in connection with claims 1, 8 and 17, and additionally wherein the cobalt film

is deposited at a temperature less than 200°C (note claims 2, 9 and 18), more specifically at a temperature less than 100°C (note claims 3, 10 and 20), even more specifically at a temperature less than 50°C (note claims 4, 11 and 21); and/or temperatures of the first-, second- and third-stage heat treatments as in claims 6, 13-15 and 19; and/or wherein the temperature of the first-stage heat treatment is equal to the deposition temperature of the oxidation barrier film, as in claim 12; and/or wherein the deposition time of the cobalt film is 15 seconds or less (see claim 25), or wherein the deposition time of the cobalt film and deposition time of the oxidation barrier film are each less than 15 seconds (see claim 16); and/or materials of the oxidation barrier film, as in claim 22; and/or wherein in the step of depositing the cobalt film the silicon substrate is cooled (see claim 26), or wherein in this first step the silicon substrate is held by an electrostatic chuck which dissipates heat from the silicon substrate (see claim 30); and/or wherein the second- and third-stage treatments are carried out in non-oxidizing atmospheres, as in claim 24; and/or wherein the temperature at which the cobalt film is deposited is a temperature lower than that at which a reaction layer of any cobalt silicide is formed (see claims 27-29).

The present invention relates to a fabrication technique for use in the manufacture of a semiconductor integrated circuit device, and, in particular, relates to a technique effective for forming a cobalt silicide layer on, for example, the surface of a source and drain of a MISFET formed in a silicon substrate.

As a known technique of forming cobalt silicide, there is a technique of depositing a Co film and a TiN film (oxidation barrier film) on the surface of the source and drain of a silicon substrate, forming a dicobalt silicide film by application of a first heat treatment,

removing the TiN film and unreacted Co by wet etching, and forming a cobalt disilicide film by application of a second heat treatment at a temperature ranging from 700°-900°C.

As a result of careful investigation of the deposition of a Co film by sputtering and subsequent heat treatment procedures, the present inventors have found the following. That is, in a conventional Co silicide process, when a cobalt film is deposited over a silicon substrate by sputtering, an undesired reaction layer is formed on the interface between the cobalt film and the silicon substrate during formation of the cobalt film, owing to an increase in the substrate temperature caused by, e.g., collision energy of the cobalt. This reaction layer is apt to have an uneven thickness, so as to deteriorate flatness of an interface between the silicon substrate and cobalt disilicide layer formed by subsequent heat treatment. The uneven surface shortens the distance between the bottom of the source and drain and the bottom of the silicide layer, leading to an increase in junction leakage current. Moreover, in further conversion of the silicide to form cobalt disilicide, such reaction layer formed upon originally depositing the cobalt film remains at the interface between the cobalt disilicide layer and the silicon substrate, increasing parasitic resistance and causing a problem of signal delay. Note, for example, pages 3 and 4 of Applicants' Substitute Specification.

Against this background, Applicants provide a process wherein the increase in junction leakage current is reduced. In particular, Applicants have found that by depositing the cobalt at such a low temperature that a silicide is <u>not</u> formed at the interface between the cobalt and silicon of the substrate <u>during the deposition</u>, with subsequent heat treatments taking place in order to form the silicide, it is possible to

planarize the interface between the substrate and the finally-formed silicide layer composed mainly of cobalt disilicide, thereby preventing an increase in junction leakage current. Moreover, by forming the cobalt film at a low temperature and preventing generation of a reaction layer between silicon and cobalt at the interface between the substrate and the cobalt film during film formation, the subsequent silicide reaction can be allowed to proceed smoothly. See page 16, lines 10-13; and from page 21, line 9 through page 22, line 3, of Applicants' Substitute Specification.

Furthermore, since a well-formed cobalt disilicide layer is formed, by converting the cobalt monosilicide, a cobalt monosilicide layer or dicobalt silicide layer having a high resistance does not remain at the interface between the substrate and the cobalt disilicide layer, improving conductivity of the formed silicide structure.

In addition, Applicants have found that by limiting the time period of cobalt deposition to 15 seconds or less, and by cooling the substrate during cobalt deposition, the desired deposition at low temperature can be achieved, thereby avoiding formation of silicide during cobalt deposition and thereby avoiding junction leakage current.

It is emphasized that according to the present invention, the cobalt layer does not react with silicon of the silicon bare surface, during the time of the cobalt deposition, because if an unwanted cobalt silicide layer is formed between the interface of the cobalt layer and silicon layer, at the time of the cobalt deposition, then a resultant cobalt silicon interface has larger resistivity and/or larger leakage current when compared with a cobalt disilicide layer only, because the dicobalt silicide or cobalt monosilicide has larger resistivity and/or larger leakage current.

Inoue discloses a method of forming a silicide layer on the surface of a gate electrode or the surface of a source or drain diffusion layer of an insulating gate type field effect transistor. The method includes forming a refractory metal silicide layer having a first phase structure, and then heat treating to change the refractory metal silicide layer having the first phase structure into a refractory metal silicide layer having a second phase structure. See column 4, lines 9-15. This patent discloses that the semiconductor substrate can be heated during performing a deposition operation of the refractory metal, in order to form the refractory metal silicide layer. See column 4, lines 16-20. This patent also discloses that in order to form a refractory metal silicide layer having the first phase structure, the refractory metal film may be deposited in a vacuum state; and, then, the semiconductor substrate may be heated in the vacuum state to change the refractory metal film into the refractory metal silicide layer having the first phase structure. See column 4, lines 26-31. Note also column 4, lines 32-43 and 53-65. Note also column 5, lines 1-8, reciting that the refractory metal is deposited in a state in which the semiconductor substrate is heated. See further column 6, lines 48-50 and 53-55, describing that in the sputtering at the described temperature of about 450°C, only a part of the surface of the diffusion layer 3 is silicided, with a Co_2Si film being formed in the silicidation. Note also column 9, lines 3-11 of this patent, stating that the Co_2Si film is formed at the same time as the sputtering film formation process is performed. Note also column 10, lines 56-66.

It is respectfully submitted that <u>in Inoue the temperature at which the cobalt is deposited is a temperature at which a silicide is formed</u>, and, e.g., a <u>silicide is formed</u> at the interface with the silicon <u>as the cobalt is deposited</u>. Such technique would have

neither taught nor would have suggested, and in fact would have taught away from, the presently claimed subject matter, including wherein in the step of depositing cobalt, the cobalt film is deposited at a temperature lower than a temperature at which a reaction layer of silicon and cobalt is formed at the interface between the silicon substrate and the cobalt film, and advantages thereof as discussed in the foregoing; and/or the other features of the present invention, and advantages thereof.

In the paragraph bridging pages 2 and 3 of the Office Action mailed July 14, 2005, and in a footnote on page 3, the Examiner contends that the deposition temperature of the cobalt film, 450°C, in Inoue is lower than a temperature at which a reaction layer of silicon and cobalt is formed. This contention by the Examiner is respectfully traversed. It is respectfully submitted that from the express teachings of Inoue the cobalt is reacted with the silicon at this temperature of 450°C. In this regard, attention is respectfully directed to the following in column 10, line 64 through column 11, line 4, of Inoue where it is stated that after the sputtering film formation, "the heat treatment temperature is set to about 450°C, and the heat treatment time is about 30 sec. Through the heat treatment, the cobalt atoms of the cobalt film 32 diffuse to the surfaces of the N-type source and drain diffusion layers 29, the surfaces of the P-type source and drain diffusion layers 30 and the surfaces of the gate electrodes 25 via the barrier film 31 to form the Co_2Si film 33 on these surfaces."

As can be seen from the above-quoted material, clearly the reaction takes place in Inoue at a temperature at 450°C, the same temperature as described in this reference at which deposition of the cobalt occurs. Clearly the Examiner errs in saying that the deposition temperature of the cobalt film, 450°C, "is lower than a temperature at

which a reaction layer of silicon and cobalt is formed". To the contrary, it is respectfully submitted that Inoue would have neither taught nor would have suggested the presently claimed subject matter, including the temperature at which the cobalt is deposited, such temperature being maintained until the end of the deposition.

Attention is also directed to column 6, lines 48-62 of Inoue. Therein, it is described that the film formation by the sputtering method is performed at the high-temperature of about 450°C, and that in the sputtering at such temperature, only a part of the surface of the diffusion layer 3 is silicided, and that in the silicidation a Co_2Si film is formed. Clearly, Inoue discloses a reaction layer of cobalt silicide being formed during the deposition of a cobalt film, teaching away from the present invention.

It is respectfully submitted that the additional teachings of the secondary applied references, Murphy, et al. and Agnello, et al., would not have rectified the deficiencies of Inoue, such that the presently claimed invention as a whole would have been obvious to one of ordinary skill in the art.

Murphy, et al. discloses a technique for deposition of cobalt on a silicon substrate for the formation of cobalt silicide, wherein the cobalt is simultaneously deposited on the silicon substrate while the silicon substrate is being cleaned of native oxides on the surface of the silicon. See column 1, lines 6-13. As to the methods for depositing cobalt while simultaneously cleaning the native oxide, note column 2, line 46 through column 3, line 11; this discloses electrically connecting the deposition device and substrate to a substrate ground circuit, for simultaneously cleaning the silicon of the native oxide and depositing cobalt. Note also column 4, lines 1-7.

Even assuming, arguendo, that the teachings of Murphy, et al. were properly combinable with the teachings of Inoue, such combined teachings would have neither disclosed nor would have suggested the presently claimed invention, including wherein the cobalt film is deposited at a temperature lower than a temperature at which a reaction layer of silicon and cobalt is formed at the interface between the silicon substrate and the cobalt film, during the entire period of depositing the cobalt, and advantages thereof, and/or other features of the present invention as discussed previously, and advantages thereof.

As applied by the Examiner, it is noted that Murphy, et al. discloses deposition of the cobalt film at a temperature as high as 300°C. It is respectfully submitted that such disclosure as in Murphy, of a wafer temperature during the cobalt deposition process, would not have disclosed, nor would have suggested, deposition of cobalt at a temperature lower than a temperature at which a reaction layer of the cobalt and silicon at the interface therebetween is formed, as in the present claims, and advantages thereof.

Moreover, it is emphasized that Murphy, et al. discloses cobalt film formation while simultaneously cleaning the substrate of a native oxide film, wherein, e.g., the cobalt film formation is on a native oxide of the silicon substrate, by applying a current flow to the silicon substrate. It is respectfully submitted that in Murphy, et al., the cobalt film is formed on the silicon substrate by cleaning a native oxide on the silicon substrate by application of current. Taking the teachings of this reference as a whole, as required under 35 USC 103, and even taking such teachings together with the teachings of the other applied references, including Inoue, it is respectfully submitted that the combined

teachings would have neither disclosed nor would have suggested the depositing of the cobalt film on a bare silicon surface, at the temperature as in the present claims. It is respectfully submitted that only through hindsight use of Applicants' disclosed invention, which of course is improper under 35 USC 103, would one of ordinary skill in the art have utilized the temperature of deposition in Murphy, et al., in connection with a bare silicon substrate surface. Using the teachings of Murphy, et al. as a whole, as required under 35 USC 103, it is respectfully submitted that the combined teachings of the references would have neither disclosed nor would have suggested the presently claimed subject matter, including wherein the cobalt film is deposited at a temperature lower than a temperature at which a reaction layer of silicon and cobalt is formed on the interface between the bare silicon substrate surface and the cobalt film, with this temperature being maintained until the end of depositing the cobalt film.

Agnello, et al. discloses a method for controlling interface roughness of a low resistivity electrical contact, wherein a cobalt alloy or nickel alloy is employed in forming the electrical contact. The method described in Agnello, et al. includes forming a cobalt alloy or nickel alloy over a silicon-containing substrate; optionally forming an oxygen barrier layer over the alloy layer; annealing the alloy layer at a temperature which is effective in forming a silicide layer; and removing the optional oxygen barrier layer and any remaining alloy layer. See column 2, lines 32-44. Note also column 4, lines 24-41, 57 and 58. See, further, column 5, lines 5-9.

It is emphasized that Agnello, et al. discloses cobalt alloy deposition. It is respectfully submitted that one of ordinary skill in the art concerned with cobalt deposition would not have looked to cobalt alloy deposition, forming cobalt alloy silicide.

Moreover, there would have been no motivation to have applied teachings in connection with depositing cobalt alloy, for forming cobalt alloy silicide, to the deposition of a cobalt film and forming cobalt silicide therefrom.

Even assuming, arguendo, that the teachings of Agnello, et al. were properly combinable with the teachings of Inoue, or properly combinable with the combined teachings of Inoue and Murphy, et al., such teachings would have neither disclosed nor would have suggested the presently claimed invention, including deposition of a cobalt film, at such a temperature lower than a temperature at which a reaction layer is formed between the silicon and cobalt at the interface therebetween, this temperature being maintained until the end of the cobalt depositing, and advantages thereof, and/or the other features of the present invention as discussed previously and advantages thereof. It is again emphasized that Agnello, et al. discloses deposition of a cobalt alloy film.

Specifically, it is emphasized that according to the present invention the cobalt is deposited at a relatively low temperature for not reacting cobalt and silicon during the deposition, notwithstanding that during the deposition heating of the substrate occurs. Reaction due to such heating of the substrate is avoided according to various features of the present invention, including cooling of the substrate, and/or especially wherein the deposition takes place in 15 seconds or less.

Clearly, various embodiments of Inoue expressly disclose simultaneous deposition and reaction. Note, for example, disclosures in columns 4 and 5 of Inoue. It is respectfully submitted that there is no express disclosure in Inoue that the deposition is performed at a temperature lower than a temperature at which a reaction layer of silicon and cobalt is formed at the interface between the substrate and the cobalt film.

Docket No. 1374.43296X00
Serial No. 10/733,377
October 14, 2005

It is again emphasized that Murphy, et al. discloses cobalt film formation on a native oxide of the substrate, while applying a current flow to the silicon substrate. In contrast, according to the present invention the cobalt film is deposited on a bare silicon surface. It is respectfully submitted that the combined teachings of Murphy, et al. and of Inoue do not address the problem according to the present invention, arising in depositing cobalt on the bare silicon, nor the solution thereof wherein an uneven silicide is avoided so as to avoid, inter alia, junction leakage current.

The Examiner's attention is directed to the time period of cobalt deposition (that is, a period less than 15 seconds) as in various of the present claims. As described in the last paragraph on page 15 of Applicants' Specification, a temperature increase occurs during cobalt deposition, due to collision of cobalt molecules on the silicon surface. It is respectfully submitted that when cobalt molecules collide to the silicon wafer, the silicon wafer temperature rises causing a reaction between a cobalt film and silicon film surface at the interface. By limiting the time of cobalt film deposition, reaction between the cobalt film and silicon film surface, due to the temperature increase caused by such collision, can be avoided. In this regard, note that temperature increase can occur even where the silicon wafer is located on a wafer chuck using a coolant, so that the cobalt film sputtering time as in the present claims achieves advantages in avoiding reaction between the cobalt and the silicon; and it is respectfully submitted that the cobalt deposition time, and advantages thereof, according to the present invention, would have neither been disclosed nor would have been suggested by the applied prior art.

Docket No. 1374.43296X00
Serial No. 10/733,377
October 14, 2005

In view of the foregoing comments and amendments, and noting the concurrently filed RCE Transmittal, entry of the present amendments, and reconsideration and allowance of all claims presently pending in the application, are respectfully requested.

Applicants request any shortage of fees due in connection with the filing of this paper be charged to the Deposit Account of Antonelli, Terry, Stout & Kraus, LLP, Deposit Account No. 01-2135 (case 1374.43296X00), and credit any excess payment of fees to such Deposit Account.

Respectfully submitted,

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